

**Close out and Final report for
NASA Glenn Cooperative Agreement NCC3-856**

Photovoltaic Engineering

Introduction

The Ohio Aerospace Institute through David Scheiman and Phillip Jenkins provided the Photovoltaics Branch at the NASA Glenn Research Center (GRC) with expertise in photovoltaic (PV) research, flight experiments and solar cell calibration. NASA GRC maintains the only world-class solar cell calibration and measurement facility within NASA. GRC also has a leadership role within the solar cell calibration community, and is leading the effort to develop ISO standards for solar cell calibration. OAI scientists working under this grant provided much of the expertise and leadership in this area.

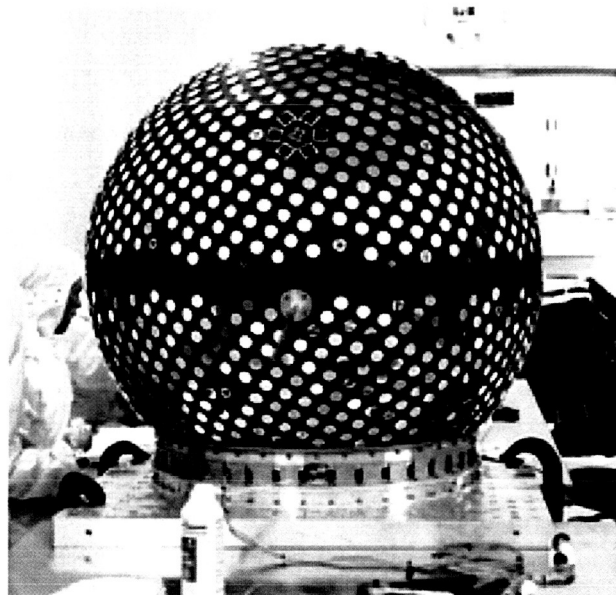
Calibration Facilities

The Solar Cell Evaluation Laboratory is constantly being modified and upgrades as funds and technology permit, handling new programs at NASA. During the course of this grant, the solar simulator used to measure was modified to better match the AM0 spectrum by adding two additional light sources (Triple Source Solar Simulator). A motorized temperature controlled measurement stage was installed to provide in-plane measurements between mounted and un-mounted cells is now a state-of-the-art facility. An Extended Temperature solar cell test plate was also added to measure cells for near-sun and deep space missions including the moon and mars. It is the only facility in the world that can measure solar cells under deep space and near sun conditions using a triple source simulator. These are well suited to help the new exploration initiatives at NASA.

Flight Experiments

Starshine 3 Flight Experiment

The Starshine 3 satellite was put into orbit on September 30, 2001 as part of the Kodiak Star mission. The Starshine 3 primary mission is to measure the atmospheric density in the upper atmosphere and serve as a learning outreach project for primary and secondary school age children. Starshine 3 also carried a power technology experiment Designed and built under this grant. Starshine 3 has a small, 1 Watt power system using state-of-the-art components. These cells have twice the power-to-area ratio as traditional silicon solar cells and a third more power than GaAs cells.



The Starshine 3 Satellite

Starshine 3 also carries novel integrated microelectronic power supplies (IMPS). The five IMPS on Starshine 3 each consist of a 1 cm × 1cm GaAs solar array, a lithium battery and a charge control circuit all contained on approximately one square inch of printed circuit board. The idea behind an IMPS unit is to allow greater flexibility in circuit design with a power source not tied to the central bus. Each IPS will be used to provide 25 microwatts of continuous power throughout the mission.

In 2002 data from the Starshine 3 satellite was collected and analyzed under this grant. Two papers summarizing the results from Starshine 3 were published in 2002. They were:

“First Results From the Starshine 3 Power Technology Experiment,” Phillip Jenkins, Thomas Kerslake, David Scheiman, David Wilt, Robert Button, Thomas Miller, Michael Piszczor and Henry Curtis, proceedings of the IEEE 29th Photovoltaics Specialists Conference, New Orleans, Louisiana, May 19–24, 2002.

“Results from the Advance Power Technology Experiment on the Starshine 3 Satellite,” Phillip Jenkins, David Scheiman, David Wilt, Ryne Raffaele, Robert Button, Thomas Kerslake, Michael Batchelder, Don Lefevre, R. Gilbert Moore, proceedings of the 16th Annual Small Satellite Conference, AIAA/Utah State University, August 12–15, 2002.

Forward Technology Solar Cell Experiment

The Forward Technology Solar Cell Experiment (FTSCE) is operated by the Naval Research Lab to evaluate solar cells in space. NASA GRC and OAI support this experiment with electronics, experiment design, solar cell calibration and operations support. This experiment will be placed on the ISS during STS-114, and mounted on the exterior of the station for approximately one year. FTSCE contains active electronics to measure the performance of many new technology solar cells, including thin film and state-of-the-art crystalline cells. Many of the solar cells used for this experiment were tested at NASA GRC before shipping to NRL. The technical leadership under this grant was used to develop all aspects of the experiment, including specimen types, electronic measurement circuitry, and operations design and support.

A total of 39 solar cells are included on FTSCE. The technologies include state-of-the-art and next generation multijunction InGaP/GaAs/Ge, heteroepitaxial GaAs/GeSi/Ge, and amorphous Si and CuIn(Ga)Se₂ thin film solar cells. The primary experiments are the triple-junction (3J) InGaP/GaAs/Ge based technologies from Spectrolab (SPL) and Emcore. In each case, the current state-of-the-art technology (ITJ for SPL and ATJM for Emcore) and the next generation technology (UTJ for SPL and BTJ for Emcore) are included. In addition, the Emcore ATJM devices include the new monolithic bypass diode. The SPL panel includes two DJ InGaP/GaAs/Ge solar cells that serve as control cells. The manufacturer according to their standard practices assembled the Emcore and SPL experiments on aluminum honeycomb rigid array substrates. The electronics monitor temperature, sun position, and take current vs. voltage curves for 36 cells when the desired temperature and sun angle are achieved. During the course of the FTSCE operations, OAI will provide commands to uplink to FTSCE based on the experiment goals. Data will be collected and analyzed and compared to pre-flight calibration values, to monitor changes in performance due to space environment effects.

Space Station

Work is ongoing to support testing for the space station solar panels. Early on, sample coupons were thermal cycled at GRC to evaluate the design of the solar array, recently, cells were tested at low light intensities and temperatures to determine if the astronauts were at risk being near the panel electrical output during eclipse.

Thomas Kerslake and David Scheiman, "Off-Nominal Performance of International Space Station Solar Array Wing Under Orbital Eclipse Lighting Scenarios" will be published at the 3rd International Energy Conversion Engineering Conference, DD760, 15–18 Aug 2005.

Solar Cell Applications

Advanced solar cell technology may make possible missions and innovative, low mass and low-cost spacecraft design which would otherwise be impossible with existing technology. It is a significant part of the NASA mission to constantly evaluate the effect of new technology on spacecraft design in order to select the most promising new technologies with the potential for greatest impact on lowering spacecraft cost and mass and decreasing the cycle time of bringing a new technology to commercial readiness. In this work investigations of the influence of power-system technology on spacecraft design, and develop innovative designs and mission-enabling technologies for missions were studied. Out of this effort an improved technique for concentrator cells was developed.

Scheiman, D.; Sater, B.L.; Chubb, D.; Jenkins, P.; and Snyder, D., "Measurement and Characterization of Concentrator Solar Cells II," 18th Space Photovoltaic Research and Technology Conference, Cleveland, Ohio, NASA/CP-2005-213431, September 2003.

Solar Cell Calibration Activities

In-house measurement, thermal cycling and calibration activities of the NASA GRC Photovoltaic branch were supported. Design and fabrication of a multi-source AM0 solar simulator was completed. OAI and NASA GRC organized an international round robin calibration of multi-bandgap cells. This activity is part of a larger effort to develop an ISO multi-bandgap solar cell calibration standard. Cells for the round robin were calibrated by the NASA GRC Lear jet and flown on the JPL and CNES balloons. Upgrades to the Lear jet solar cell calibration facility now allow routine measurements of full I-V curves on the jet. A summary of results from the first of three round robin activities was published at the 3rd World Conference on Photovoltaic Energy Conversion held in 2003.

David Brinker David Scheiman Bruce Anspaugh Robert Mueller, Trinidad Gomez, Emilio Fernandez Lisbona, Kazuhiro Aoyama, Mitsuru Imaizumi, Valérie Pichetto, Yang Yiqiang, Chris Goodbody and Phillip Jenkins, "Results from the 1st international AM0 calibration round robin of silicon and GaAs solar cells," Proceedings of the 3rd World Conference on Photovoltaic Energy Conversion, held May 11–18, 2003, paper number 3P-C3-42.

Photoluminescence Laboratory

OAI supported the NASA GRC Photovoltaic Branch with photoluminescence measurements throughout the year. This work helped both the III-V epitaxial growth research as well as quantum dot research.